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Ultrasonic delay lines for millisecond delays

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SUMMARY

A one day visit to the Corning Glass Company's works at Bradford, Pennsylvania, was paid by the writers in order to discuss the performance of Corning glass delay lines. This report summarizes that day's discussions.

1. INTRODUCTION

There are many techniques used in television or projected for use that require devices suitable for delaying the television signal by durations which range from the order of a few microseconds or less to 20 ms, the latter being the duration of one field of European television.

It is perhaps worthwhile to distinguish between storage and delay in so far as television is concerned. Delay may be defined as storage for a short period of time, usually less than one picture period with automatic access and feed-out. Video tape magnetic recording is an example of storage whereas electrical and acoustic lines may be regarded as examples of delay. Magnetic drums may also be included in the latter category.

Vertical aperture correction which is now beginning to come into vogue requires, at the least, a delay equal to the duration of one scanning line and, at the best, both the already mentioned delay and a delay equal to the duration of a television field.

The interpolation required for one type of line-store standards conversion requires at least one delay equal to the duration of a scanning line and at best possibly three such delays. In one form of field-store standards conversion five delays of 3.1/3 ms are required and in another form nine delays are required each different from the other, and covering a range of between 66.2/3 μs to $8{\cdot}5\dot{3}$ ms.

The visit to the Corning Company was undertaken mainly with the thought of field-store standards conversion in mind, although the advantages of a field delay applied to image-transfer standards conversion and other similar techniques must not be overlooked.

The obtaining of a field delay (20 ms) seems, at the present time, to be unlikely, nevertheless the Corning Company did say that they would be prepared to supply a delay line of the order of 9 ms but at reduced performance, and this is an example of a situation in which further development work is required. The discussions at Cornings were concentrated mainly on an ultrasonic delay line having a delay of the order of 3·5 ms.

2. GENERAL INFORMATION

During the visit we were taken on a short tour of their factory, where we saw the blanks of fused synthetic amorphous silica* as they arrived from the main Corning works in New York State. Also on show were several delay lines going through production. All the delay lines having significant delays in the millisecond region consist of polygonal discs about ½-inch thick, with an input electro-mechanical transducer stuck on to one of the facets of the polygon and an output electro-mechanical transducer stuck to another facet. An acoustic wave is launched from the input facet into the material and is reflected back and forth across the disc from one facet to another until the output facet is reached, whereupon an electrical signal is obtained from the output transducer. The delay discs have 'diameters' which vary from one foot to several feet, and the number of traverses inside the material from facet to facet frequently exceeds fifteen.

Electro-mechanical transducers have apertures which are many wavelengths wide (the major dimension of the facet on to which the transducer is stuck) and thus the acoustic wave is launched into the medium with considerable directivity. Notwithstanding this fact, unwanted spurious signals such as echoes and what is described as clutter or secondaries appear in the output circuit from the delay line. These are due to a multiplicity of causes: the beam width of the main lobe is not narrow enough and so multipath propagation occurs due to reflexions from the upper and lower major surfaces of the disc. Also the width of the beam after many reflexions becomes wider than the facets on the edge of the polygon, thus giving rise to unwanted echoes; the angles of the various facets may not be precise enough and the surfaces may not be flat enough. Means for reducing unwanted reflexions are adopted, such as painting the outside surfaces of the disc and unsatisfactory parts of the facets with a material which reduces the reflexion coefficient inside the medium. It can be seen from this description that the problem of obtaining a satisfactory delayed signal free from excessive clutter and echoes bears some relation to problems of studio acoustics and of transmission of v.h.f. and u.h.f. waves over irregular terrain. It is therefore likely that some similarity will exist between the methods of test used in these examples and those suitable for ultrasonic delay lines. The television signal to be delayed must be modulated on to a carrier wave; 20 Mc/s being a typical frequency.

Several methods of testing these delay devices come to mind, the first to be mentioned is that which is applied to the specification of v.h.f. and u.h.f. transmitter aerial matching where a directional coupler at the input to the feeder enables reflexion coefficients to be measured using sinusoidal signals at various frequencies within the passband of the signal to be transmitted.

* Corning material code number 7940.

The method of test which seems to be favoured by the Corning Company bore some resemblance to those used in studio acoustic work and also those used for television transmission equipment. Cornings use pulsed carrier techniques, although their specification of the exact shape of the nominally square-wave modulation used did not seem to be very precise, but some 'tailoring' of the leading and trailing edges of the pulses was done in order to avoid testing the delay line, and in particular, of course, its transducers with a pulse whose spectrum was wider than that of the real signal for which the delay device had been built.

A 3·5 ms delay line, which we saw being pulse tested, revealed many long-term (spaced from the main pulse by more than 2 μs) echoes but of satisfactorily low magnitude. There was, however, a short-term echo, part of which appeared coincident with the latter half of the 2 μs test pulse. The specification of this kind of spurious signal seems to require some care, and the method of transmission circuit testing known as K-rating comes to mind.

It will be apparent from what has been said that the visit revealed the need for co-ordination between buyer and supplier with regard to testing methods. Cornings were very clear and businesslike with regard to this matter. If we are to obtain delay lines from them at the relatively cheap prices which they quote, this will only be achieved by our being careful not to alter in any way the specification which we send them to fulfil. Any changes after a specification has been mutually agreed would invalidate the agreed prices. This means that our specification must be quite definite and clear.

3. THE SPECIFICATION

Most of the day spent at Bradford was occupied in going through an example specification for a 3.1/3 ms ultrasonic delay device, and obtaining Corning's comments. The specification and Corning's remarks are given below:

3.1. Technical specification

Item: Nominal delay

Proposal: 3.1/3 ms

Comments by Corning: This delay presents no difficulty. However, Cornings have had discussions with clients from time to time because the method of measuring delay has not been clearly specified. For example: is the delay to be regarded as the time difference between the centres of gravity of an input and an output pulse? Or is it to be measured in terms of the delay of a wave-front such as a band-limited unit step modulated on to a radio-frequency carrier? If the latter is the case, the time of rise of the test signal must be specified with care.

Item: Tolerance on delay

Proposal: +0, -2 μs

Comments by Corning: The grinding tolerance is ± 0·25 μs at a specified operating temperature such as 80°C or 20°C, or any other reasonable value of temperature.

Item: Temperature stability of delay

Proposal: Not to exceed -100 parts per million per °C

Comments by Corning: -80 parts/million/degree C.

Item: Band-centre frequency

Proposal: Any value in the range 20 to 60 Mc/s acceptable. All lines provided must be capable of operation with identical carrier frequency

Comments by Corning: This depends upon the value of the delay required. Approximately 20 Mc/s would be suitable for shortish delays, and nearer to 30 Mc/s for a 3.1/3 ms delay device.

Item: Passband

Proposal: At least 7 Mc/s between the 3 dB points. The curve should have only one maximum and no points of inflexion. The terminating impedance should be stated

Comments by Corning: 7 Mc/s between 3 dB points can be achieved. A curve having only one maximum and no points of inflexion is not achievable if the specification is given in such broad terms, but if irregularities in the 'swept' response curve of magnitude smaller than 0·5 dB peak to peak can be neglected, then a satisfactory curve can be achieved. Yes, the terminating impedance must be stated. Cornings often use the figure of 50 ohms.

Item: Level of secondaries

Proposal: The amplitude of secondaries must be more than 48 dB below the main signal over the passband

Comments by Corning: This item depends greatly upon the method of test used, and an exact answer in terms of reflexions of sine waves at given frequencies cannot be given. It seems that, assuming a 2 μs test pulse, with leading and trailing edges having rise times of the order of 0·2 μs, modulated on to a radio-frequency carrier, secondaries would occur which exceeded the 48 dB requirement specified. From figures supplied by Cornings it appears that secondaries whose magnitudes varied between -42 dB and -51 dB would be likely to occur. These figures, however, refer to secondary responses occurring outside the time occupied by the main 2 μs space. There are likely to be spurious signals which occur coincident with the main pulse, and these responses may be as high as 5 per cent or -26 dB.

Item: Insertion loss (ratio of volts across terminated output transducer and volts at input transducer)

Proposal: Not greater than 38 dB at band centre with the same termination as is used for passband measurement. The operating temperature should be stated

Comments by Corning: 38 dB insertion loss cannot be achieved. Present figures are in the region of 60 to 65 dB. It is just possible that 50 dB might be achieved at increased cost. Cornings stated that the maximum reasonable input voltage measured across the input transducer is 50 V.

Item: Input and output impedance

Proposal: Input capacity not to exceed 200 pF unless ceramic transducers are used. In the latter case the capacity can be higher since the insertion loss should be significantly better than specified above

Comments by Corning: 100 pF or less across the input terminals at the operating frequency.

Item: Size and type of fused-quartz block

Proposal: Not specified but useful information. Type means 'single decker' or 'double decker' and size refers to diameter

Comments by Corning: For a 3.1/3 ms delay a single deck would be used.

3.2. Supply information

Item: Price of prototype 3.1/3 ms delay

Comments by Corning: Approximately as already quoted in earlier correspondence with Designs Department.

Item: Price of quantity of five 3.1/3 ms delays

Comments by Corning: As above

Item: Delivery of prototype from receipt of order

Comments by Corning: Twelve weeks.

Item: Delivery of quantity of five delays from receipt of order

Comments of Corning: Confirmation of conformity with specification to be given within 30 days. Delivery of remaining four delays would be within a few weeks from this confirmation.

Item: Would Cornings be willing to negotiate the order and to carry out technical discussions direct with the BBC? Delivery via Corning's British agents would, however, be acceptable

Comments by Corning: Communication channels with Cornings at Bradford are open on the technical level, but quotations and orders must be through Electrosil (U.K.).

4. CONCLUSIONS

It will be seen from the comments offered by the Corning Company that our requirements will not be completely satisfied, and urgent consideration must be given to the question as to how much relaxation we can accept. When this has been decided a suitable specification will have to be drawn up, and it is suggested that this be submitted to the Corning Company for their comments.

5. ACKNOWLEDGEMENTS

We should like to acknowledge with gratitude the trouble taken by Mr. H.S. Craumer and Mr. A.F. Greenlaw of the Corning Company on our behalf. Both these gentlemen spent the entire day with us, and without their help our visit would have been in vain.

Our thanks are also due to Mr. W. Wharton of Research Department for the preparation of the example specification which formed the basis of our discussions.

CHS

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